A METHOD FOR FABRICATING AN INTERFERENCE DISPLAY UNIT

Field of Invention

The present invention relates to a method for manufacturing an optical interference display. More particularly, the present invention relates to a method for manufacturing an optical interference display with posts of arms.

Background of the Invention

Planar displays are popular for portable displays and displays with space limits because they are light and small in size. To date, planar displays in addition to liquid crystal displays (LCD), organic electro-luminescent displays (OLED), plasma display panels (PDP) and so on, as well as a mode of the optical interference display are of interest.

US Patent No. 5,835,255 discloses an array of display units of visible light that can be used in a planar display. Please refer to figure 1, which depicts a cross-sectional view of a display unit in the prior art. Every optical interference display unit 100 comprises two walls, 102 and 104. Posts 106 support these two walls 102 and 104, and a cavity 108 is subsequently formed. The distance between these two walls 102 and 104, that is, the length of the cavity 108, is D. One of the walls 102 and 104 is a semi-transmissible/semi-reflective layer with an absorption rate that partially absorbs visible light, and the other is a light reflective layer that is deformable when voltage is applied. When the incident light passes through the wall 102 or 104 and arrives in the cavity 108, in all visible light spectra, only the visible light with the wavelength corresponding to the formula 1.1 can generate a constructive interference and can be emitted, that is,

$$2D = N\lambda \qquad (1.1)$$

where N is a natural number.

When the length D of cavity 108 is equal to half of the wavelength times any natural number, a constructive interference is generated and a sharp light wave is emitted. In the meantime, if the observer follows the direction of the incident light, a reflected light with wavelength λ_1 can be observed. Therefore, the display unit 100 is "open".

The first wall 102 is a semi-transmissible/semi-reflective electrode that comprises a substrate, an absorption layer, and a dielectric layer. Incident light passing through the first wall 102 is partially absorbed by the absorption layer. The substrate is made from conductive and transparent materials, such as ITO glass or IZO glass. The absorption layer is made from metal, such as aluminum, chromium or silver and so on. The dielectric layer is made from silicon oxide, silicon nitrite or metal oxide. Metal oxide can be obtained by directly oxidizing a portion of the absorption layer. The second wall 104 is a deformable reflective electrode. It shifts up and down by applying a voltage. The second wall 104 is typically made from dielectric materials/conductive transparent materials, or metal/conductive transparent materials.

Figure 2 depicts a cross-sectional view of a display unit in the prior art after applying a voltage. As shown in figure 2, while driven by the voltage, the wall 104 is deformed and falls down towards the wall 102 due to the attraction of static electricity. At this time, the distance between wall 102 and 104, that is, the length of the cavity 108 is not exactly zero, but is d, which can be zero. If we use d instead of D in formula 1.1, only the visible light with a wavelength satisfying formula 1.1, which is λ_2, can generate a constructive interference, and be reflected by the wall 104, and pass through the wall 102. Because wall 102 has a high light absorption rate for light with wavelength λ_2, all the incident light in the visible light spectrum is filtered out and an observer who follows the direction of the incident light cannot observe any reflected light in the visible light spectrum. The display unit 100 is now "closed".

Refer to figure 1 again, which shows that the posts 106 of the display unit 100 are generally made from negative photoresist materials. Refer to figures 3A to 3C, which depict a method for manufacturing a display unit in the prior art. Referring to

figure 3A, the first wall 102 and a sacrificial layer 110 are formed in order on a transparent substrate 109, and then an opening 112 is formed in the wall 102 and the sacrificial layer 110. The opening 112 is suitable for forming posts therein. Next, a negative photoresist layer 111 is spin-coated on the sacrificial layer 110 and fills the opening 112. The objective of forming the negative photoresist layer 111 is to form posts between the first wall 102 and the second wall (not shown). A backside exposure process is performed on the negative photoresist layer 111 in the opening 112, in the direction indicated by arrow 113 to the transparent substrate 109. The sacrificial layer 110 must be made from opaque materials, typically metal materials, to meet the needs of the backside exposure process.

Refer to figure 3B, which shows that posts 106 remain in the opening 112 after removing the unexposed negative photoresist layer. Then, the wall 104 is formed on the sacrificial layer 110 and posts 106. Referring to figure 3C, the sacrificial layer 110 is removed by a release etch process to form a cavity 114. The length D of the cavity 114 is the thickness of the sacrificial layer 110. Therefore, different thicknesses of the sacrificial layers must be used in different processes of the different display units to control reflection of light with different wavelengths.

An array comprising the display unit 100 controlled by voltage operation is sufficient for a single color planar display, but not for a color planar display. A method in the prior art is to manufacture a pixel that comprises three display units with different cavity lengths as shown in figure 4, which depicts a cross-sectional view of a matrix color planar display in the prior art. Three display units 302, 304 and 306 are formed as an array on a substrate 300, respectively. Display units 302, 304 and 306 can reflect an incident light 308 to color lights with different wavelengths, for example, which are red, green and blue lights, due to the different lengths of the cavities of the display units 302, 304 and 306. It is not required that different reflective mirrors be used for the display units arranged in the array. More important is that good resolution be provided and the brightness of all color lights is uniform. However, three display units with different lengths of cavities need to be manufactured separately.

Please refer to figures 5A to 5D, which depict cross-sectional views of a method for manufacturing the matrix color planar display in the prior art. In figure 5A, the first wall 310 and the first sacrificial layer 312 are formed in order on a transparent substrate 300, and then openings 314, 316, 318, and 320 are formed in the first wall 310 and the sacrificial layer 312 for defining predetermined positions where display units 302, 304, and 306 are formed. The second sacrificial layer 322 is then conformally formed on the first sacrificial layer 312 and in the openings 314, 316, 318, and 320.

Please referring to figure 5B, after the second sacrificial layer 322 in and between the openings 314 and 316, and in the openings 318 and 320 is removed by a photolithographic etch process, the third sacrificial layer 324 is conformally formed on the first sacrificial layer 312 and the second sacrificial layer 322 and in the openings 314, 316, 318 and 320.

Please refer to figure 5C, which shows that the third sacrificial layer 324 in the openings 318 and 320 remains but the remainder of the third sacrificial layer 324 is removed by a photolithographic etch process. Next, a negative photoresist is spin-coated on the first sacrificial layer 312, the second sacrificial layer 322, and the third sacrificial layer 324, and in the openings 314, 316, 318 and 320, and fills the all openings to form a negative photoresist layer 326. The negative photoresist layer 326 is used for forming posts (not shown) between the first wall 310 and the second wall (not shown).

Please refer to figure 5D, which shows that a backside exposure process is performed on the negative photoresist layer 326 in the openings 314, 316, 318 and 320 in a direction of the transparent substrate 300. The sacrificial layer 110 must be made at least from opaque materials, typically metal materials, to meet the needs of the backside exposure process. Posts 328 remain in the openings 314, 316, 318 and 320 after removing the unexposed negative photoresist layer 326. Subsequently, the second wall 330 conformally covers the first sacrificial layer 312, the second sacrificial layer 322, the third sacrificial layer 324 and posts 328.

Afterward, the first sacrificial layer 312, the second sacrificial layer 322, and the third sacrificial layer 324 are removed by a release etch process to form the display units 302, 304, and 306 shown in figure 4, wherein the lengths d1, d2, and d3 of three display units 302, 304, and 306 are the thicknesses of the first sacrificial layer 312, the second sacrificial layer 322, and the third sacrificial layer 324, respectively. Therefore, different thicknesses of sacrificial layers must be used in different processes of the different display units, to achieve the objective for controlling reflection of different wavelengths of light.

There are at least three photolithographic etch processes required for manufacturing the matrix color planar display in the prior art, to define the lengths of the cavities of the display units 302, 304, and 306. In order to cooperate with the backside exposure for forming posts, metal materials must be used for making the sacrificial layer. The cost of the complicated manufacturing process is higher, and the yield cannot be increased due to the complicated manufacturing process.

Therefore, it is an important subject to provide a simple method of manufacturing an optical interference display unit structure, for manufacturing a color optical interference display with high resolution, high brightness, simple process and high yield.

Summary of the Invention

It is therefore an objective of the present invention to provide a method for manufacturing an optical interference display unit structure, and the method is suitable for manufacturing a color optical interference display with resolution and high brightness.

It is another an objective of the present invention to provide a method for manufacturing an optical interference display unit structure, and the method is suitable for manufacturing a color optical interference display with a simple and easy manufacturing process and high yield.

It is still another objective of the present invention to provide a method for manufacturing an optical interference display unit structure, and the method is suitable for manufacturing a color optical interference display with posts.

In accordance with the foregoing objectives of the present invention, one preferred embodiment of the invention provides a method for manufacturing an optical interference display unit structure. The first wall and a sacrificial layer are formed in order on a transparent substrate, and then an opening is formed in the first wall and the sacrificial layer. The opening is suitable for forming posts therein. Next, a photoresist layer is spin-coated on the sacrificial layer and fills the opening. A photolithographic process patterns the photoresist layer to define a support with an arm. The support and the arm are used for a post, and to define the length of the arm. Due to the exposure of the photoresist layer with the help of a mask, the sacrificial layer no longer must be opaque materials such as metal and the like; common dielectric materials are also used for making the sacrificial layer.

The second wall is formed on the sacrificial layer and posts, and then baking is performed on the posts. The arm may generate displacement as the pivot of the support caused by stress action. An end of the arm adjacent to the support has less displacement, but another end of the arm has more displacement. The displacement of the arm may change the position of the second wall. Afterward, the sacrificial layer is removed by a release etch process to form a cavity, and the length D of the cavity may not be equal to the thickness of the sacrificial layer due to the displacement of the arm.

The arms with the ratios of various lengths to thicknesses have various amounts of stress, and displacements and directions generated by arms are various during baking. Therefore, the arms with the ratios of various lengths to thicknesses may be used for controlling the length of the cavity, instead of the various thicknesses of the sacrificial layers used in the various processes of the display units to control various wavelengths of light reflected in the prior art. There are many advantages in the above way. First of all, the cost drops drastically. The thickness of the cavity in the prior art is the thickness of the sacrificial layer, and the sacrificial layer needs to be removed at the end

of the process. However, using an upward displacement of the arms in the present invention increases the length of the cavity, so that the length of the cavity is greater than the thickness of the sacrificial layer, even if the thickness of the sacrificial layer is substantially decreased while forming the same length of cavities. Therefore, the material used for manufacturing the sacrificial layer is substantially reduced. The second, the process time is shortened. The release etch process of the metal sacrificial layer in the prior art consumes lots of time, because the sacrificial layer is removed by an etching gas that must permeate the spaces between the posts. The present invention utilizes a mask for a front exposure, so the sacrificial layer can be transparent materials such as dielectric materials, instead of opaque materials such as metal and the like as in the prior art. Besides, the thickness used by the sacrificial layer can be substantially reduced, so the time required for the release etch process can be also drastically decreased. Third, the color optical interference display formed by using posts can substantially reduce complexity of the process. The difference in the ratios of lengths to thicknesses of arms of posts is used for changing the stress of the arms. After baking, various optical interference display units have various lengths of the cavities due to the displacement of arms, such that reflected light is changed with various wavelengths, such as red, green, and blue lights, so as to obtain various color lights.

In accordance with another an objective of the present invention, one preferred embodiment of the invention provides a method for manufacturing a matrix color planar display structure. Each matrix color planar display unit has three optical interference display units. The first wall and a sacrificial layer are formed in order on a transparent substrate, and then an opening is formed in the first wall and the sacrificial layer. The opening is suitable for forming posts therein. Next, a photoresist layer is spin-coated on the sacrificial layer and fills the opening. A photolithographic process patterns the photoresist layer to define a support with an arm. The support and the arm are used for a post, and to define the length of the arm. A single photolithographic process can accomplish the arms of three optical interference display units. Due to the exposure of the photoresist layer with the help of a mask, the sacrificial layer no longer must be an

opaque material such as metal and the like; common dielectric materials are also used for making the sacrificial layer.

The second wall is formed on the sacrificial layer and posts, and then baking is performed on the posts. The arm may generate displacement as the pivot of the support caused by stress action. An end of the arm adjacent to the support has less displacement, but another end of the arm has more displacement. The displacement of the arm may change the position of the second wall. Afterward, the sacrificial layer are removed by a release etching process to form a cavity, and the length D of the cavity may not be equal to the thickness of the sacrificial layer due to the displacement of the arm.

The first wall is the first electrode, and the second wall is the second electrode. Each T-shaped arm of the optical interference display unit has variable length and stress. Therefore, after baking, each optical interference display unit has various cavity lengths due to the various displacements of arms, such that reflected light is changed with different wavelengths, such as red, green, and blue light. These in turn provide various color lights for a matrix color planar display structure.

In accordance with the color planar display consisting of an array of optical interference display units disclosed by the present invention, the advantages of a matrix color planar display according to the prior art are retained, including high resolution and high brightness, as well as the advantages of a multi-layered color planar display with a simple process and high yield in the prior art. It is understood that the present invention discloses an optical interference display unit which not only keeps all advantages of the prior optical interference color planar display such as high resolution, high brightness, simple process and high yield during forming arrays, but also increases the window during processing and raises the yield of the optical interference color planar display.

It is to be understood that both the foregoing general description and the following detailed description are examples, and are intended to provide further explanation of the invention as claimed.

Brief Description of the Drawings

These and other features, aspects, and advantages of the present invention will be more fully understood by reading the following detailed description of the preferred embodiment, with reference made to the accompanying drawings as follows:

Figure 1 depicts a cross-sectional view of a display unit in the prior art;

Figure 2 depicts a cross-sectional view of a display unit in the prior art after applying a voltage;

Figures 3A to 3C depict a method for manufacturing a display unit in the prior art;

Figure 4 depicts a cross-sectional view of a matrix color planar display in the prior art;

Figures 5A to 5D depict cross-sectional views of a method of manufacturing a matrix color planar display in the prior art;

Figures 6A to 6C depict a method for manufacturing an optical interference display unit according to one preferred embodiment of this invention;

Figure 6D depicts a cross-sectional view of an optical interference display unit according to one preferred embodiment of this invention; and

Figures 7A to 7D depict a method of manufacturing a matrix color planar display structure according to the second preferred embodiment of this invention.

Detailed Description of the Preferred Embodiment

In order to provide more information of the optical interference display unit structure, the first embodiment is provided herein to explain the optical interference display unit structure in this invention. In addition, the second embodiment is provided to give further description of the optical interference color planar display formed with an array of the optical interference display unit.

Embodiment 1

Figures 6A to 6C depict a method for manufacturing an optical interference display unit according to a preferred embodiment of the invention. Please referring to figure 6A first, a first electrode 502 and a sacrificial layer 506 are formed in order on a

transparent substrate 501. The sacrificial layer 506 is made of transparent materials such as dielectric materials, or opaque materials such as metal materials. An opening 508 is formed in the first electrode 502 and the sacrificial layer 506 by a photolithographic etch process. The opening 508 is suitable for forming a post therein.

Next, a material layer 510 is formed in the sacrificial layer 506 and fills the opening 508. The material layer 510 is suitable for forming posts, and the material layer 510 generally uses photosensitive materials such as photoresists, or non-photosensitive polymer materials such as polyester, polyamide or the like. If non-photosensitive materials are used for forming the material layer 510, a photolithographic etch process is required to define posts in the material layer 510. In this embodiment, the photosensitive materials are used for forming the material layer 510, so merely a photolithographic etching process is required for patterning the material layer 510.

Please referring to figure 6B, the posts 512 are defined by patterning the material layer 510 during a photolithographic process. The post 512 has a support 514 disposed in the opening 508, and the post 512 has arms 5121 and 5122. The same photolithographic process also defines the lengths of arms 5121 and 5122. The thicknesses of the arms 5121 and 5122 are decided in the step of forming the material layer 510. A second electrode 504 is formed on the sacrificial layer 506 and the post 512.

Reference is next made to figure 6C. A thermal process is performed, such as baking. Arms 5121 and 5122 of the post 512 may generate displacement as the pivot of the support 514 caused by stress action. Ends of the arms 5121 and 5122 adjacent to the support 514 have less displacement, but other ends of the arms 5121 and 5122 have more displacement. The displacement of arms 5121 and 5122 may change the position of the second electrode 504. Thereafter, the sacrificial layer 506 is removed by a release etch process to form a cavity 516.

The optical interference display unit made in figures 6A to 6C is shown in figure 6D, which depicts a cross-sectional view of an optical interference display unit of one

preferred embodiment of this invention. An optical interference display unit 500, which may be a color changeable pixel unit, at least comprises a first electrode 502 and a second electrode 504. The first electrode 502 and the second electrode 504 are approximately parallel to each other. The first electrode 502 and the second electrode 504 are selected from the group consisting of narrowband mirrors, broadband mirrors, non-metal mirrors or the combination thereof.

Posts 512 support the first electrode 502 and the second electrode 504. The arms 5121 and 5122 of the posts 512 are raised upwards. The length of the cavity is the thickness of the sacrificial layer in the optical interference display unit structure in the prior art. If the thickness of the sacrificial layer is D, the length of the cavity is D, too. In this embodiment, a cavity 516 is formed between the first electrode 502 and the second electrode 504 supported by posts 512. The posts 512 have the arms 5121 and 5122. The ratio of lengths to thicknesses of the arms 5121 and 5122 decide stress thereof, and a dotted line 5121' and a dotted line 5122' label the positions prior to performing a thermal process of the arms 5121 and 5122. After performing the thermal process, the arms 5121 and 5122 may generate displacement; therefore the position of the second electrode 504 changes from the original position labeled by the dotted line 504', and the length D' of the cavity 516 between the first electrode 502 and the second electrode 504 changes from the original length D. Since the length of the cavity 516 changes, the frequency of a reflected light changes following the length of the cavity 516. In general, when posts 512 are made from polyamide compounds, the ratio of lengths to thicknesses of the arms 5121 and 5122 is from 5 to 50, and the length D' of the cavity 516 is approximately 1.5 to 3 times the length D of the thickness of the sacrificial layer. Of course, the ratio of lengths to thicknesses of the arms 5121 and 5122 can be changed to make the length D' of the baked cavity 516 smaller than the thickness of the sacrificial layer.

In this invention, the materials suitable for forming posts 512 include positive photoresists, negative photoresists, and all kinds of polymers such as acrylic resins, epoxy resins and so on.

Embodiment 2

Figures 7A to 7D depict a method for manufacturing a matrix color planar display structure according to the second preferred embodiment of this invention. Reference is made to figure 7A first, illustrating formation of the first electrode 602 and a sacrificial layer 604 in order on a transparent substrate 601. The sacrificial layer 604 can be made of transparent materials such as dielectric materials, or opaque materials such as metal materials. Openings 606, 608, 610, and 612 are formed in the first electrode 602 and the sacrificial layer 604 by a photolithographic etch process, and openings 606, 608, 610, and 612 are suitable for forming posts therein.

Next, a material layer 614 is formed on the sacrificial layer 604 and fills the openings 606, 608, 610, and 612. The optical interference display unit 624 is defined by openings 606 and 608, the optical interference display unit 626 is defined by openings 608 and 610, and the optical interference display unit 628 is defined by openings 610 and 612. The material layer 614 is suitable for forming posts, and is generally made from photosensitive materials such as polyester or non-photosensitive materials such as polyester, polyamide or the like. If a non-photosensitive material is used for forming the material layer 614, a photolithographic etching process is required to define posts on the material layer 614. In this embodiment, the photosensitive material is used for forming the material layer 614, so a single photolithographic etch process is sufficient for patterning the material layer 614.

Please refer to figure 7B. A photolithographic process patterns the first material layer 614, so as to define posts 616, 618, 620, and 622. The posts 616, 618, 620, and 622 have supports 6161, 6181, 6201, and 6221 disposed in the openings 606, 608, 610, and 612, respectively. The posts 616, 618, 620, and 622 also have arms 6162, 6182, 6183, 6202, 6203, and 6222. The arms 6162, 6182, 6183, 6202, 6203, and 6222 are the same in length. A second electrode 630 is formed on the sacrificial layer 604, posts 616, 618, 620, and 622.

Please refer to figure 7C. A thermal process is performed, such as baking. The arms 6162, 6182, 6183, 6202, 6203, and 6222 of the posts 616, 618, 620, and 622

may generate displacement as the pivot of the supports 6161, 6181, 6201, and 6221 caused by stress action. There is less displacement at the ends of the arms 6162, 6182, 6183, 6202, 6203, and 6222 adjacent to the supports 6161, 6181, 6201, and 6221, but more displacement at the other ends of the arms 6162, 6182, 6183, 6202, 6203, and 6222. The displacements of the arms 6162 and 6182 are the same, the displacements of the arms 6183 and 6202 are the same, and the displacements of the arms 6203 and 6222 are the same. But there are various displacements among three above pairs of the arms. Therefore, there are various changes in the positions of the second electrode 630 caused by the arms 6162 and 6182, the arms 6183 and 6202, and the arms 6203 and 6222.

Thereafter, reference is made to figure 7D. The sacrificial layer 604 is removed by a release etch process to form the cavities 6241, 6261, and 6281 of the optical interference display units 624, 626, and 628. The cavities 6241, 6261, and 6281 have various lengths d_1, d_2, and d_3, respectively. When the optical interference display units 624, 626, and 628 are "open", as shown as the formula 1.1, the design of lengths d_1, d_2, and d_3 of the cavities 6241, 6261, and 6281 can generate the reflected light with different wavelengths, such as red (R), green (G), or blue (B) light.

The lengths d_1, d_2, and d_3 of the cavities 6241, 6261, and 6281 are not decided by the thickness of the sacrificial layer, but by the lengths of the arms 6162 and 6182, 6183 and 6202, 6203 and 6222, respectively. Therefore, the complicated photolithographic process of the prior art to define various lengths of the cavities forming various thicknesses of the sacrificial layers is unnecessary.

In accordance with the color planar display consisting of the array of optical interference display units disclosed by this embodiment, the advantages of a matrix color planar display in the prior art are retained, including high resolution and high brightness, as well as the advantages of the prior art multi-layered color planar display such as simple process and high yield. Compared with the matrix color planar display in the prior art, the embodiment discloses an optical interference display unit that does not require the complicated photolithographic process in the prior art to define various

lengths of the cavities by forming various thicknesses of the sacrificial layers. The optical interference display unit thus has a simple process and high yield. Compared with the matrix color planar display in the prior art, the embodiment discloses an array of optical interference display units, in which all the optical interference display units that can generate reflected color light are located in the same plane. In other words, the incident light can reflect various color lights without passing through the multi-layered optical interference display unit; thus, the optical interference display unit has high resolution and high brightness. Furthermore, in the multi-layered optical interference display in the prior art, in order to make an incident light to pass through a former display unit and reach a latter display unit efficiently, and the result of light interference in the latter display unit (reflected light of green or blue light wavelength) to pass through a former display unit efficiently, the compositions and thicknesses of the first electrode and the second electrode of three types of display units are different. The manufacturing process is actually more complicated than expected. The process for the array of the optical interference display units disclosed by this invention is less difficult than the process in the prior art.

Although the present invention has been described in considerable detail with reference certain preferred embodiments thereof, other embodiments are possible. Therefore, their spirit and scope of the appended claims should no be limited to the description of the preferred embodiments container herein. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.